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Navigating the Energy Transition

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Between now and 2050 or so, the world will undergo a great social, economic, and technological transition. In place of the fossil fuels—oil, coal, and natural gas—that now satisfy most of our energy needs and define key aspects of contemporary civilization, a new class of renewable energy sources will come to dominate the industrial landscape. Huge arrays of wind turbines and solar panels will replace the smokestacks and refineries that now surround major cities. In place of gasoline, filling stations will provide advanced biofuels or hydrogen to supply fuel cells. High-speed rail lines will connect major cities, while light rail will snake through large and small cities and their suburbs. Our homes, schools, factories, and offices will be designed to use as little energy as possible for heating, cooling, and illumination.

From our vantage point today, we can readily envision the world of 2050, and picture how the development of alternative sources of energy will alter our lives and those of our descendants. What is *less* clear is how we will get from here to there. At the conclusion of the process, the global economy and its myriad transportation systems will have been reconstructed along new lines, and the human population will have learned to live in new and more environmentally sensitive ways. But the transition from our current energy system to one based largely on renewables will be fraught with danger and crisis, as the supply of existing fuels dwindles and that of alternative fuels proves inadequate to make up the difference. Navigating this great transition could well prove the most difficult challenge facing the human community in the twenty-first century—and it is a challenge that has already forced itself upon us.

Why will this prove such a great challenge, and why is it upon us now? Let us begin with the obvious: An abundant supply of affordable energy is essential for the effective functioning of the world economy. Without such a supply, the global economy slows and suffers all sorts of disorders and trauma. We saw ample evidence of this in the spring and summer of 2008, when oil prices reached record levels, causing intense misery for the automotive, airline, and tourism industries, as well as for farmers, truckers, and commuters. High oil prices were not the direct cause of the financial meltdown of late 2008, but they were a significant factor in the subprime mortgage crisis that ultimately triggered the meltdown, in that they boosted the monthly costs faced by hard-pressed homebuyers in remote exurbs (the epicenter of the subprime pandemic). The price of gasoline only dropped when the economic crisis suppressed international demand, and it will stay low only so long as the crisis persists. As soon as economic activity rebounds, oil prices will climb again.

Energy is tied to another critical concern of the emerging era: global climate change. The largest single constituent of the greenhouse gases that are deemed responsible for planetary warming is carbon dioxide (CO_2), and the principal source of the CO_2 now accumulating in the outer atmosphere is the burning of fossil fuels to generate electricity or power motor vehicles. The more we rely on fossil fuels for these purposes, the greater will be the emissions of CO_2 and the faster the warming of the planet. The obvious solution to this peril is to reduce consumption of oil, coal, and natural gas. But this will require accelerating the development of climate-friendly alternatives, and this will take time and a great infusion of capital. Meanwhile,

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we still need abundant supplies of energy—affordable energy—and this puts a premium on the increased output of fossil fuels.

The intensified pursuit of fossil fuels to satisfy vital economic requirements will also bear on yet another key aspect of the current epoch: growing geopolitical rivalry among the major powers. In a world in which every nation must endeavor to satisfy its requirement for an adequate supply of energy, the competition for access to the world's remaining reserves of oil and natural gas is destined to become increasingly fierce. This has led the major consuming nations to employ every means at their disposal—including military means—to gain advantage in the competitive struggle over diminishing stocks of energy. In some cases, this has led to an influx of arms into areas of instability, as in Africa and Central Asia; in others, to the permanent deployment of military forces, as in the Persian Gulf and Caspian Sea basin. As the competition for fossil fuels increases, these geopolitical rivalries are likely to gain further momentum.

So the three greatest concerns of the moment—the global economy, the environment, and geopolitical competition—are directly tied to the nature of the world's existing energy mix. And this is where the problem lies. The types of energy on which we currently rely to satisfy most of our needs are not likely to prove adequate to meet future requirements—yet the harder we work to increase their availability, the more we doom the planet to catastrophic climate disorder and recurring geopolitical crisis.

Only a radical increase in the tempo of change can ensure that alternative sources of energy will be available in 2025.

THINGS AS THEY ARE

To grasp better these underlying realities, it is essential to examine the world's existing energy balance. At present, most of the world's energy is derived from fossil fuels. According to the US Department of Energy (DOE), fully 86 percent of total world energy consumption was satisfied in 2005, the most recent year for which comprehensive figures are available, by such fuels—36.7 percent by oil, 26.5 percent by coal, and 23.2 percent by natural gas. An additional 7.7 percent was provided by hydropower and renewable sources of energy, and 5.9 percent by nuclear power (see the table on page 28).

It is the relative abundance of fossil fuels that has largely propelled the great economic expansion of the past 65 years, enabling not only the reconstruction of Europe and Japan after World War II but also the industrialization of Brazil, China, India, South Korea, Taiwan, and other rapidly growing economies. Over the course of this remarkable epoch, the industrialized nations erected a global civilization based on easy access to affordable fuels and electricity to power a vast array of motor vehicles, aircraft, computers, and other power-hungry devices. All this has been made possible because the international energy industry has—until now—largely succeeded in continually expanding the global output of oil, coal, and natural gas. Clearly, if this civilization is to continue to thrive in the years ahead and be extended to even more countries in the developing world, this extraordinary feat of energy-supply expansion will have to be repeated again and again.

Indeed, the DOE projected in the summer of 2008 that worldwide energy demand would grow by 50 percent between 2005 and 2030, from 462 to 695 quadrillion British thermal units (BTUs). This represents an enormous increase—the 233 quadrillion BTUs that must be added over the next quarter century is the equivalent of current energy consumption by the United States, Europe, and Japan combined. Most of this added energy, the DOE assumes, will have to be supplied by the most common and well-developed fuels: oil, coal, and natural gas. According to DOE projections, these three fuels will provide approximately the same share of world energy in 2030—85.8 percent—as they did in 2005.

If the energy industry were capable of supplying all this added fossil-fuel energy in 2030, that would be good news for the global economy, in that the older industrialized nations could maintain their high levels of consumption while the developing world experienced fast consumption growth. But it is extremely unlikely that the industry will be capable of meeting this objective. Although the net supply of fossil fuels may continue to increase, the global availability of oil will probably go into decline well before the end of this period. Natural gas supplies are likely to remain stagnant. This leaves only coal—the most

WORLD ENERGY CONSUMPTION BY SOURCE

2005 (Actual) and 2030 (Projected)

Energy Source	2005 Actual		2030 Projected	
	Consumption quad BTUs	Percent of world total	Consumption quad BTUs	Percent of world total
Oil and biofuels	169.4	36.7	229.3	33.0
Natural gas	107.4	23.2	164.7	23.7
Coal	122.5	26.5	202.2	29.1
Nuclear	27.5	5.9	39.4	5.7
Hydropower, Renewables, others	35.5	7.7	59.0	8.5
Total, world	462.2	100.0	694.7	100.0

Source: US Department of Energy, *International Energy Outlook 2008* (Washington, DC: 2008), Table A2, p. 97.

CO_2-intensive of the three fossil fuels—as a rising source of energy. The bottom line: insufficient energy supplies combined with rising greenhouse-gas emissions.

The most troubling aspect of this equation involves oil. Although the DOE and many oil industry officials claim that global petroleum supplies will be sufficient to satisfy international requirements between now and 2030, many experts doubt that this will prove to be the case. In its *World Energy Outlook* released on November 12, 2008, the International Energy Agency (IEA), a Paris-based organization affiliated with the Organization for Economic Cooperation and Development, warned that global oil supplies may not be adequate to meet global needs in the years ahead. The agency gave three reasons that this might be so. First, existing fields are running out of oil at a faster rate than previously thought. Second, most newly developed oil fields are smaller and less productive than those currently in operation. And third, investors are shying away from costly and complex projects in "frontier" oil regions like the deep waters of the Gulf of Mexico, the Gulf of Guinea, Siberia, and the Caspian Sea.

Of the three reasons, perhaps the most startling was the revelation concerning the rapid depletion of existing fields. Although the world possesses tens of thousands of operating wells, most of our oil is drawn from several hundred giant reservoirs that produce hundreds of thousands of barrels per day. Almost all of these fields were discovered a quarter of a century or more ago, and many have already passed their peak level of daily output and are now experiencing a steady rate of decline. Previously, energy analysts assumed that this rate of decline was, on average, about 4 to 5 percent per year across the board—a conceivably manageable rate assuming sufficient investment in new oil field development by the major oil companies. But after conducting a survey of the world's 800 top-producing oil fields, the IEA concluded that the natural decline rate of these reservoirs is closer to 9 percent per year, a wholly unexpected and troubling outcome that tells us we are moving far more rapidly toward the end of the Petroleum Age than was previously assumed.

Replacing 4 percent of the world's oil supply every year is one thing; replacing 9 percent is a vastly greater challenge, given the huge cost and difficulty of developing new fields. Although the oil companies are spending greater amounts every year to locate and develop promising deposits, they are finding fewer and smaller fields. And the reservoirs they do manage to bring on line tend to empty out much faster than the giants discovered earlier, in the golden years of discovery following World War II. For example, the two major discoveries of the 1960s, the North Slope of Alaska and the North Sea, are already experiencing rapid rates of output decline. Only two large discoveries have been made since then—the Kashagan field in the Caspian Sea and the Tupi field in Atlantic waters off Rio de Janeiro—and both pose extraordinary technical challenges to the companies hoping to bring them into production.

The only way to ensure adequate supplies of oil in the years ahead is for the world's oil companies to make mammoth investments in drilling rigs, pipelines, and other infrastructure to bring new reservoirs into production. According to the IEA, satisfying anticipated world demand in 2030 will require a minimum of $350 billion per year (in 2007 dollars) in such investments *every year* between now and then. But much of this money will have to be spent on facilities in the hurricane-prone waters of the Gulf of Mexico and the Atlantic, or in conflict-prone areas of Africa, the Middle East, and Central Asia—which gives pause to investors.

Even before the onset of the world's current economic crisis, many investors were deterred by the rising cost of such ventures and, in the case of projects in Africa, the Middle East, and the former Soviet Union, by the potential for big losses as a result of conflict, sabotage, corruption, or governmental intervention. Since the economic crisis erupted, investors have become even more skittish, proving extremely reluctant to commit large sums to any projects that entail risks of this sort. Thus, even though oil resources could prove abundant in some of these areas, it is questionable whether they will be brought on line in time to satisfy global needs. As noted by the IEA in its November 12 report: "It cannot be taken for granted" that the major private oil companies and government-owned oil firms like Saudi Aramco will allocate sufficient funds "to keep up the necessary pace of investment."

What this means, in sum, is that the worldwide supply of petroleum is likely to fall short of projected global requirements in the decades to come. To put this in further perspective, the most recent edition of the DOE's *International Energy Outlook* projects that world oil supply will rise from 83.6 million barrels per day in 2005 to 95.7 million barrels in 2015, 101.3 million in 2020, and 112.5 million in 2030. (This includes conventional oil plus "nonconventional" supplies such as shale oil, Canadian tar sands, and biofuels.) But many experts, drawing on the sort of analysis presented above, now believe that world production will reach a peak in output well before 2030, probably between 2010 and 2015, at a level of about 95 million barrels per day. They believe output will remain at about that level for several years and then commence an irreversible decline—dropping far below the DOE's estimate of 112 million barrels for 2030. This means that, by 2030 or so, the world could be looking at a shortfall of anywhere from 25 to 30 million barrels of oil per day—a huge plunge in the global supply of energy.

MORE CARBON NEEDED

Clearly, any effort to satisfy world fuel requirements in the years after 2015 will require a significant increase in the production of *other* sources of energy. In the first instance, this will lead to greater dependence on the two other fossil fuels, natural gas and coal. Many experts believe that the output of gas and coal can be substantially augmented to compensate for the declining availability of oil. But this, too, could prove problematic.

Without going into great detail, any increase in the global output of natural gas will confront many of the same sorts of hurdles encountered in the case of petroleum. Like petroleum, gas is a finite substance produced by natural phenomena over many millions of years and is often found in similar geological formations. Just as the global output of oil is expected to reach a maximum or peak level in the not-too-distant future, so too will natural gas attain a peak in the third or fourth decade of the century.

Competition for access to the world's remaining reserves of oil and natural gas is destined to become increasingly fierce.

Also as in the case of oil, many of the world's largest reservoirs of gas have already been located and exploited, suggesting that less-attractive fields—those in remote locations like northern Alaska, eastern Siberia, and the Arctic Ocean—are all that remain for future development. Some additional gas is trapped in coal beds, shale rock, and other distinctive geological formations that can be mined with appropriate technologies. Industry experts believe it will be possible to exploit all these remote and "nonconventional" sources of gas. However, the cost will be high, and it is doubtful that these sources will ever prove sufficient to replace more than a tiny share of the energy now provided by oil.

Any increase in the consumption of natural gas will also entail significant geopolitical risks. No less than 56 percent of the world's known gas reserves are held by just three countries—Russia, Iran, and Qatar—and these three have recently taken steps to solidify their control over the fuel's future utilization by creating the nucleus of a "natural gas OPEC." Several other leading gas producers, including Algeria, Libya, Saudi Arabia, and the Central Asian states, have also expressed interest in forming such a cartel, suggesting the likelihood of future constraints on natural gas's global availability. This is precisely the sort of environment in which conflict could arise over access to sources of natural gas, much as has been the case in past years over access to sources of petroleum.

Coal presents a rather different set of problems. Coal is expected to remain relatively abundant well into the middle of the century (after which it, too, will reach a peak in production and go into decline). Moreover, large deposits of it are located in major energy-consuming nations like China, India, Russia, and the United States. With existing technology, coal is the cheapest fuel available for producing electricity, so its use is growing in many developing countries as well as in the United States. According to the DOE, China's coal consumption will grow by 120 percent between 2005 and 2030; in India it will grow by 80 percent, and in the United States by 31 percent. Coal can also be used as a feedstock for synthetic gas and diesel fuel, making it an attractive substitute for natural gas and oil as these materials become increasingly scarce.

However, any increase in coal consumption using existing combustion technologies will result in a speed-up of global warming and an onslaught of climatic disasters. This is so because coal releases more carbon dioxide per unit of energy generated than do the other two fossil fuels. Scientists and engineers are working on a technique to separate the carbon from the coal and bury it before combustion occurs—so-called carbon capture and storage (CCS) technology. But plants using this technique are expected to be far more costly than existing ones, and at this point no commercial facility employs this method. As the impacts of global warming grow more severe, power companies will come under greater pressure to use this technology, but it is unlikely that it will have achieved widespread adoption by 2030. What is more likely, at that point, is an increase in conventional coal technology, producing a heightened risk of catastrophic climate change.

ALTERNATING CURRENT

Obviously, the best hope for all of us on the planet (and for our descendents) is for the energy industry—and the world's major governments—to invest in a massive, rapid expansion of alternative sources of energy, especially renewables like solar, wind, geothermal, and advanced (non-edible) biofuels. These sources are not derived from finite materials like oil, natural gas, and coal but are infinitely replaceable, and release very little or no carbon in their operation. Eventually, when the great energy transition is completed, most of the world's energy supply is likely to be derived from these sources. But increasing the amount of energy supplied by these sources will prove an uphill and expensive struggle—and until that process is completed, we could be in for very difficult times.

At present, renewables and hydropower supply only 7.7 percent of the world's energy. According to the latest projections from the DOE, this figure will only rise to 8.5 percent by 2030, not including biofuels; with the addition of biofuels, it would rise by another percentage point or two. (Nuclear power provides another 5.9 percent of world supply currently. Although nuclear power is likely to continue playing a small but significant role in satisfying world energy needs, it poses so many safety, nonproliferation, and waste disposal challenges, as well as legal and financial challenges to investors, that it is unlikely to exceed single digits in its net contribution to the global supply.) Even if we assume these figures are overly pessimistic, this is hardly enough to compensate for the decline in oil or our perilous reliance on coal. Only a tripling or quadrupling in the share of energy provided by renewables and advanced biofuels by 2030 can put us far along the path of a successful transition.

Several factors account for the slow pace of renewable energy's development. To begin with, major utilities and their government backers have long been accustomed to relying on oil, coal, gas, and nuclear power, so they have been reluctant to make major investments in alternative sources of power. According to the IEA, three-quarters of the world's projected output of electricity in 2020 (and more than half in 2030) will come from generation facilities that are already in operation today—almost all of them powered by fossil fuels or nuclear energy. Furthermore, most of the new plants under construction—especially in China and India, where the demand for added electricity is greatest—are of this type. It will be very hard, under these circumstances, to increase the share of energy provided by alternative sources.

In addition, wind, solar, biofuels, and other, more advanced sources of energy face many obstacles that must be overcome before they can replace fossil fuels on a very large scale. Wind and solar power pose a common set of problems. Both collect energy intermittently, and so are off line for considerable periods of time. Also, both achieve their maximum effectiveness in remote areas like the American Southwest (in the case of solar power) or high plains (for wind) that are far removed from areas of greatest demand, and so lack adequate connectivity to the electrical grid. Biofuels pose different problems. Most ethanol in the United States is manufactured from corn ears, a valuable source of food for humans and animals; the very process of making it, moreover, entails a large and wasteful input of energy.

To overcome these various obstacles, huge sums must be spent—on developing new storage batteries so that energy collected from wind and the sun can be harvested when the supply is great and later dispersed when it is not; on an expanded (and more efficient) electrical grid connecting vast solar arrays and wind farms to major population centers; and on advanced biofuels using nonfood plant matter as a feedstock, and chemical rather than thermal means of manufacturing ethanol. Additional investment is also needed to develop other promising but as-yet unproven technologies, including hydrogen fuel cells, wave energy, and fusion reactors.

Most of our oil is drawn from several hundred giant reservoirs and many have already passed their peak.

But even with a huge increase in spending on energy alternatives, such as President-elect Barack Obama and his supporters in Congress have proposed, it is highly unlikely that renewables, advanced biofuels, and climate-safe (that is, CCS) coal will be available on a large enough scale in 2030 to make up for what is likely to be an inadequate supply of oil and natural gas. Increased efforts at conservation will help, as will greater reliance on public transportation. But it is hard to escape the conclusion that in the middle stages of the great transition, from roughly 2020 to 2040, global energy supplies—except for climate-threatening coal—will be insufficient to meet global needs.

COMPETITION HEATS UP

In a world constrained by inadequate stockpiles of energy, we can expect intense geopolitical competition for whatever supplies *are* available at any given time. As the US National Intelligence Council (NIC) suggested in its November 2008 assessment of the likely strategic environment in 2025: "The rising energy demands of growing populations and economies may bring into question the availability, reliability, and affordability of energy supplies. Such a situation would heighten tensions between states competing for limited resources, especially if accompanied by increased political turbulence in the Middle East and a general loss of confidence in the ability of the marketplace to satisfy rising demands."

The NIC report, *Global Trends 2025: A Transformed World*, is particularly illuminating because it focuses on the same period discussed in this article: the midpoint in the great transition from fossil fuels to a post-petroleum economy. The report suggests, as well, that the world of 2025 will be well on its way toward the adoption of alternative forms of energy, yet will still be highly dependent on fossil fuels to satisfy most day-to-day requirements. At the same time, according to the report, significant problems will have arisen in boosting output of oil and gas to match rising worldwide demand. The result, it predicts, is an environment of perceived scarcity. In such an environment, political leaders will see no option but to employ any means at their disposal to maximize their own country's supplies—even at the risk of conflict with equally desperate competitors.

"In the worst case," observes the NIC report, "this could lead to interstate conflicts if government leaders deem assured access to energy resources to be essential to maintaining domestic stability and the survival of their regime." Even in the absence of war, competition for energy will have important geopolitical implications as states undertake strategies to hedge against the possibility that existing energy supplies will not meet rising demands. For example, "energy-deficient states may employ transfers of arms and sensitive technologies and the promise of a political and military alliance as inducements to establish strategic relationships with energy-producing states."

Read deeper into the NIC report, and you find numerous portrayals of a world torn apart by relentless struggle over precarious supplies of oil and natural gas. Central Asia comes in for particular attention as a site of potential conflict among the United States, Russia, and China for control over that region's hydrocarbon reserves. Africa, a growing source of oil for the United States and China, is also seen as a potential site of geopolitical rivalry. Even the Arctic—increasingly open to oil and gas drilling as a result of global warming—is deemed a possible locale for conflict.

These kinds of rivalries are doubly dangerous. Not only do they risk full-scale war among the major powers, with all the destructive effects that would entail, but they would also consume mammoth sums of money that could otherwise be devoted to the development of energy alternatives, thereby slowing the transition to a post-petroleum industrial system. In fact, a world of recurring energy wars could make a successful transition impossible, or delay it until such time as the world economy had contracted substantially and global warming had advanced much further than it might have otherwise.

It is painfully evident, then, that the current pace of transition is far too slow to achieve the intended results in time to avert global catastrophe. Only a radical increase in the tempo of change can ensure that alternative sources of energy will be available in 2025 and beyond to compensate for the decline in oil and prevent increased dependence on unsafe coal. This will require vastly greater expenditures on efforts to realize the full potential of wind power, solar, geothermal, advanced biofuels, hydrogen, and climate-safe coal, along with increased investment in public transportation. The world of 2050 can be a bright, livable environment in which renewable energy sources power prosperity—but only if we take steps now to accelerate the transition from our current energy system to its unavoidable replacement. ■